

MSFC Russian Rocket Engine Design Course
July 16-18, 2003
UAH Tom Bevell Conference Center

Employees interested in attending, please email: chris.robinson@nasa.gov or 544-1422.
Registration deadline is **July 7, 2003**. Once employees are confirmed for attendance, additional information will be provided. Seats are limited for this course. The outline of the lecture, agenda, and bio are provided below:

Course Description:

Outline of lecture series by Professor Bazarov

1. Survey and comparative analysis of Liquid Rocket Engine Injector Design in Russia
 - 1.1. Methods of injection and classification of injector types.
 - 1.2. Fluid injectors.
 - 1.3. Gas-liquid (pneumatic) injectors.
 - 1.4. Other methods of combustible mixture preparation.
2. Fluid injectors dynamics.
 - 2.1. Liquid Rocket Engine as a dynamic system.
 - 2.2. The role of injection in an engine.
 - 2.3. Spray injectors dynamics.
 - 2.4. Swirl injectors dynamics.
3. Gas-liquid injectors dynamics.
 - 3.1. Dynamic scheme of gas - liquid injector.
 - 3.2. External mixing gas - liquid injector dynamics.
 - 3.3. Linear dynamics of gas - liquid injector with a mixer.
 - 3.4. Self - pulsation in coaxial injectors.
4. Influence of transient processes in injectors on propellants atomization and mixing.
 - 4.1. Induced pulsation in fluid injectors.
 - 4.2. Induced pulsation in gas - liquid injectors.
 - 4.3. Self - pulsation in injectors.
 - 4.4. Fluctuations of gas flow and its influence on injection.
5. Influence of stationary and dynamic parameters on combustion efficiency and stability.
 - 5.1. Influence of stationary design and regime parameters.
 - 5.2. Influence of dynamic parameters: amplification coefficient, phase angle, pulsation frequency.
6. Injectors for variable thrust Liquid Rocket Engines.
 - 6.1. Classification of thrust control methods.
 - 6.2. Throttling.
 - 6.3. Variation of propellants density.
 - 6.4. Flow area variation.
 - 6.5. Mass flow coefficient variation.

7. Swirl injectors flow angle control and stabilization.
 - 7.1. Geometrical characteristics of injectors.
 - 7.2. Nozzle profiling.
 - 7.3. Narrowing of swirl flow.
8. Damping and filtration of pressure and mass flow pulsation in feed lines and injectors.
 - 8.1. High frequency damping.
 - 8.2. High frequency filtration.
 - 8.3. Wide frequency range damping.
 - 8.4. Low frequency pulsation suppression.
9. Injectors for ultra - fine atomization.
 - 9.1. Wetted porous insert, blown through by gas flow.
 - 9.2. Wetted porous insert with transparent gas channels.
 - 9.3. Dry porous insert with transparent channels for liquid flow.
12. New type of injection by means of crossed channels.
 - 12.1. Liquid injectors.
 - 12.2. Pneumatic injectors.
13. Methods to improve atomization and mixing in injectors.
 - 13.1. Viscous losses minimization.
 - 13.2. Non-stationary atomization.
 - 13.3. Additional kinds of energy applications for atomization.

MSFC Russian Rocket Engine Design Course

July 16, 2003

8:00am – 9:15am	Lecture 1
9:15am – 9:45am	Discussion/Break
9:45am-11:00am	Lecture 2
11:00am-11:30am	Discussion
11:30am-12:45pm	Lunch
12:45pm-2:00pm	Lecture 3
2:00pm-2:30pm	Discussion/Break
2:30am-3:45pm	Lecture 4
3:45pm-4:15pm	Discussion

July 17, 2003

8:00am – 9:15am	Lecture 5
9:15am – 9:45am	Discussion/Break
9:45am-11:00am	Lecture 6
11:00am-11:30am	Discussion
11:30am-12:45pm	Lunch
12:45pm-2:00pm	Mr. Bob Sackheim's Russian Experience
2:00pm-2:30pm	Discussion/Break
2:30am-3:45pm	Lecture 7
3:45pm-4:15pm	Discussion

July 18, 2003

8:00am – 9:15am	Lecture 8
9:15am – 9:45am	Discussion/Break
9:45am-11:00am	Lecture 9
11:00am-11:30am	Discussion
11:30am-12:45pm	Lunch
12:45pm-2:00pm	Lecture 12
2:00pm-2:30pm	Discussion/Break
2:30am-3:45pm	Lecture 13
3:45pm-4:15pm	Discussion

Vladimir Bazarov

Professor Bazarov is currently the Head of the Combustion Dynamics Division at Moscow Aviation Institute School of Rocket Engines. He received his Engineering Diploma, the Ph.D., and the Dr.Sci from the Moscow Aviation Institute in 1962, 1967, and 1986, respectively. He is an Academician of the Russian Academy of Cosmonautics and is an internationally known expert in the design of gas-liquid injectors. He was awarded the Korolev Gold medal for achievements in space science research in 1979, the Gagarin Gold Medal for achievements in the support of manned space flight in 1984, Silver medals and Diplomas for inventions "Platelet multi-swirl injector" and "New technology of ultra-fine liquid atomization," and First Prize, Diploma and Big Medal of the Gross Foundation for outstanding achievements in the design of ecologically clean propulsion systems in 1994.

Selected Publications of V. Bazarov

"Liquid -Propellant Rocket Engine Injector Dynamics," (in co-authorship with Prof. Vigor Yang), *Journal of Propulsion and Power*, Vol. 14, No. 5, September-October 1998.

"Non-Linear Interactions in Liquid-Propellant Rocket Engine Injectors," AIAA 98-4039, 34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 13-15, 1998, Cleveland, OH.

"Injector Research for Shuttle OMS Upgrade Using LOX/Ethanol Propellants." (in co-authorship with R.D. Woodward, K.L. Miller, G.F. Guerin, S. Pal and R.J. Santoro), AIAA 98-3816, 34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, July 13-15, 1998, Cleveland, OH.

"Swirl Injector Hydraulics," 9th Annual Symposium on Propulsion, Cleveland, OH Oct. 1997.

"Unsteady Processes During Atomizing of Liquid with the Help of Gaseous Stream," Proceedings of 11th ILASS-Europe Conference on Liquid Atomization and Spray Systems, Nurnberg, Germany, 1995.

"Influence of Propellant Injector Dynamic Characteristics on Combustion Stability and Efficiency," IAF-92-0645, 43rd Congress of International Astronautical Federation, Washington DC.1992.

"Dynamics of Gas-Liquid Injectors," M., *Mashinostroyenie*, 1991, 287 pp (in co-authorship with A.V.Andreev, A.L.Dushkin, S.S.Grigoriev and L.A.Lul'ka; in Russian, Chinese).

"Technology of Unsteady Fuel Combustion," Information List No. 88-51, Moscow Technical Information Center, 1988 (in Russian).

"Studies of Fuel Atomizers Unsteady Operation and Their Influence on Combustible Mixture Preparation," *Teplo-Energetica*, No. 7, Moscow, 1983, pp. 41-43 (in Russian).

"Study of Self-Oscillatory Liquid Film Flow Regime in Coaxial Air Stream." (in co-authorship with L.A.Lul'ka), *Soviet Aeronautics*, Vol. 21, No. 3, Allerton Press, 1978, pp. 12-15.